Semi-annual Eos Contract Report -- Report #24
Period: July 1 - December 31, 1993
Remote Sensing Group (RSG), Optical Sciences Center (OSC) at the University of Arizona
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Contract Number: NAS5-31717
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Introduction: This report contains ten sections. Each section presents a different aspect of work performed under our contract. If appropriate, each section covers five areas; task objective, work accomplished, data/analysis/interpretations, anticipated future actions, and problems/corrective actions. The ten sections are: 1) Science team support activities; 2) SeaWiFS solar-radiation-based calibration; 3) Cross-calibration radiometers; 4) Reflectomobile; 5) Mobile laboratory; 6) Shortwave infrared (SWIR) radiometer; 7) Bi-directional reflectance distribution function (BRDF) meter; 8) Calibration Laboratory; 9) Algorithm and code development; and 10) Field experiments.

In October, Dr. Paul Spyak joined the Remote Sensing Group. He received his PhD three years ago from the Optical Science Center of the University of Arizona under the supervision of Professor W. L. Wolfe. For the past three years he has worked at Hughes, Tucson, where he established a radiometric calibration laboratory and developed calibration techniques for the thermal IR. He also was involved in IR sensor analysis. We anticipate he will continue to work in these general areas as part of our ASTER and MODIS activities.

Science Team Support Activities: This section refers to all work performed in support of MODIS and ASTER team activities as well as work performed for other sensor teams. Over the past six months this included the attendance at team and other related meetings and completing assigned action items.

ASTER Activities: S. Biggar, P. Slater, and K. Thome met September 16 at the RSG's facilities in Tucson with G. Geller, A. Kahle, and D. Nichols of JPL and H. Kieffer of the USGS in Flagstaff to discuss ASTER Level 1 processing in the United States. Slater and Thome travelled to Tokyo, Japan for the U. S. Aster Science Team Meeting November 9 and the Joint ASTER Science Team meeting November 10-12. Slater presented the status of sensor calibration at the U. S. meeting and co-chaired the Calibration Working Group Meeting for the Joint ASTER Team Meeting. Thome presented a summary of the atmospheric correction in the solar reflective to the Temperature and Emissivity Working Group. Biggar and Slater prepared a revised-ten-year budget for ASTER and submitted this to Kahle. Biggar, Slater, and Thome emailed comments to

G. Geller of JPL regarding the preliminary version of the ASTER EEDSCD. Thome supplied comments to Geller regarding the calibration portion of the ASTER System Level Requirements Document. He also sent revised Science Objectives and Statement of Work to Nichols.

MODIS Activities: Biggar and Slater travelled to Washington, D. C. for the MODIS Science Team meeting September 27 to October 1 where Slater chaired meetings of the MODIS Calibration Working Group. Slater is compiling the Calibration Plan using inputs from MCST, SBRC, and Science Team members, including those prepared by Biggar and Thome. Slater attended a Calibration Plan Review December 13-14 at Goddard Space Flight Center.

Other Eos Related Activities: Slater and Thome travelled to Torrance, Calif. where Slater chaired the Defense Landsat Program Office's Workshop on Atmospheric Correction of Landsat Imagery June 29, 30 and July 1. Thome presented two papers at the workshop, the first summarizing the atmospheric aerosols workshop sponsored by Goddard Space Flight Center in May and the second describing preliminary plans for the atmospheric correction of ASTER. Slater also co-edited the Executive Summary and Proceedings of the workshop. Slater travelled to Tokyo for the IGARSS '93 meeting where he co-chaired two sessions and presented a paper describing the solar-radiation-based calibration of SeaWiFS. Biggar and Thome travelled to Santa Barbara to repeat the SeaWiFS solar-radiation-based experiment that was performed last March. Data were successfully collected on November 1. Biggar also used the opportunity to measure the output of the SeaWiFS spherical integrating source with the visible, near-infrared transfer radiometer.

SeaWiFS Solar-Radiation-Based Calibration: The objective of this project is the preflight calibration of the SeaWiFS sensor using the sun. The idea for such a project was first raised by Slater at the SeaWiFS Science Team Meeting in January, 1993.

Biggar and Thome travelled to Santa Barbara for the calibration October 28 through November 1. No lunar data were collected because of smoke and haze. The two-hour-long solar calibration was conducted at Santa Barbara Research Center (SBRC) on November 1, 1993 by Biggar and Thome aided by A. Holmes and SBRC staff. We situated the sensor such that the solar diffuser was illuminated in the same geometry as on-orbit calibration. When the diffuser was aligned correctly, the digital counts from the sensor, while it was viewing the diffuser, were recorded for each spectral band. Then the diffuser was shadowed by a small disk that blocked the direct beam, and the digital counts were again recorded for each band. The difference, corrected for the atmospheric transmittance and the small component of diffuse light blocked by the disk, corresponds to the in-orbit illumination of the diffuser. The atmospheric transmittance was measured during the period of diffuser measurements with a solar radiometer.

Thome faxed preliminary results to A. Holmes of SBRC. The SeaWiFS-measured digital counts were received December 16 and final results based on these data will be presented at the SeaWiFS Science Team Meeting in March, 1994. These results will include a comparison between the solar-radiation-based results and the sphere-derived calibration.

Error analysis of the solar-radiation-based method indicates the results should have a 1s uncertainty of less than 2.8% for all of the SeaWiFS wavelengths. The primary source of error in the method is the atmospheric transmittance as measured by the solar radiometer. In reviewing the results, it should be realized that there are many error sources associated with both the sphere-derived and solar-based calibrations. The two that are the hardest to define are those of the solar-exo-atmospheric-spectral irradiance and the spectral irradiance of the lamp used to calibrate the sphere.

The success of this experiment last March and the preliminary success of the more current calibration has prompted interest in its use for MODIS calibration. However, the success of this type of approach must also be weighed against the risks of exposing the satellite sensor to an outdoor environment. We feel that with proper planning and care, most of these risks can be minimized to a point where this method of calibration is worthwhile.

Cross-Calibration Radiometers: This section describes work to design, fabricate, test, and calibrate a set of preflight cross-calibration radiometers (CCRs). These radiometers will cover the wavelength region from 400 to 14500 nm. To accomplish this, several separate radiometers will be constructed, each optimized for a specific portion of the spectrum. They will have very low stray light and polarization responses, exhibit sharp, well-defined fields of view and spectral response profiles, and be ultrastable with respect to temperature and time. The radiometers will be used to provide an important independent calibration and cross-calibration of the calibration facilities used by the Phase C/D contractors. The targeted completion date for all of the CCRs is the first quarter of calendar year 1995 to allow sufficient time to conduct several measurements with the CCRs at the contractor's and other calibration facilities.

VNIR CCR: The objective of this project is to design and build a 400 to 900 nm cross-calibration radiometer, test this radiometer, and write control and data acquisition software. This radiometer will be compared to NIST-traceable standards of spectral irradiance and Halon targets.

Biggar designed the radiometer with three silicon detectors in a "trap" configuration. Spectral selection is through interference filters selected by manually turning a filter wheel. Two precision apertures determine the throughput. Heating the detector assembly, filters, apertures, and amplifier to a stabilized temperature, a few degrees above ambient, provides thermal control of the system. A commercial datalogger digitizes the amplifier output, and ancillary information such as detector temperature, and controls the amplifier gain through digital output ports. This datalogger sends the serial digital data to a MS-DOS compatible computer. The entire radiometer consists of the head with filter wheel, the electronics/power supply package, connecting cables, datalogger, and computer.

Biggar began measuring several of our calibrated lamps for comparison with the recently received standard lamp from NIST. He also upgraded the data collection software. Accurately assessing the spectral transmittance of the interference filters for the instrument has proven difficult. The primary problem has been that repeated measurements of the same filter have given unacceptably different results. To remedy this, Biggar designed hardware and ordered computer software for measuring filter spectral transmittance so that we can perform the measurements in our own laboratory using the recently received Optronic monochromator system. He also investigated using the nearly refurbished Cary-14 spectroradiomter for this purpose.

The VNIR CCR was used to measure the output of the spherical-integrating source used by SBRC in the calibration of SeaWiFS. Biggar will continue working on these data as well as the data collected as part of the SeaWiFS Round Robin. A 6-inch portable SIS was received to be used with the VNIR and SWIR CCR.

SWIR CCR: The objective of this project is to design and build a 1100- to 2500-nm cross-calibration radiometer, test this radiometer, and write control and data acquisition software. This radiometer will be compared to NIST-traceable standards of spectral irradiance and Halon targets. Biggar is currently investigating the possibility of improving the existing SWIR spectroradiometer for use as a CCR.

TIR CCR: The objective of this project is to design and build cross-calibration radiometers to cover the 3000- to 14500-nm spectral region, test these radiometers, and write control and data acquisition software. This radiometer will be designed for precision only and the method of calibration is under investigation. Spyak is currently investigating the design of this radiometer and should complete the design phase by April, 1994.

Reflectomobile: The task objective is to design a vehicle and instrument package to perform field, surface reflectance measurements more accurately, efficiently and repeatably with only one person. In the past, people have carried yokes which extend the radiometers away from the walker's body to reduce shadow and other problems. This method requires the involvement of at least three people, takes about 40 minutes to cover a 0.02 km^2 site, and depends on the ability of the walker to orient the radiometer correctly. Construction of the reflectomobile is complete but tests and modifications continue.

D. Gellman submitted plans for altering the reflectomobile design to reduce shadow problems, to prevent failure of the space-frame joints, and to level the trailer. He also devised a method to cover the tow vehicle tires to reduce marking the test site's surface. Gellman modified the reflectomobile to accommodate the SWIR spectroradiometer optical head, an IR transducer, and an Exotech radiometer. The trailer hitch was modified to ensure that the trailer can be leveled regardless of the tow vehicle used, the tail lights were repaired, steel parts which had rusted were replaced with stainless steel parts, and the safety cable system for the space frame assembly was improved.

In future work, Gellman will design a method for swinging the instruments away from shadows without giving up stability. He is investigating the possibility of redesigning the space frame so that it would attach to the stake pockets of the mobile laboratory tow vehicle. Further work will be done to examine track mitigation as the tire covers did not work as planned.

Mobile Laboratory: The objective of this task is to design a mobile laboratory for 1) storage and transportation of equipment; 2) electricity (AC and DC) for equipment; 3) shelter from the sun, heat, and cold for computers and people during measurements and for all of our equipment overnight at experiment sites; and 4) a roof platform for certain instruments, especially the solar aureole meter and some meteorological instruments.

Gellman used these criteria to design the proposed version of the mobile laboratory. We intend it to consist of a fifth-wheel, gooseneck trailer towed by a pickup truck with dual rear wheels. With this arrangement we can detach the mobile laboratory at the site during multiple-day experiments; use the tow vehicle for reflectance measurements; and substitute a different tow vehicle if the pickup truck breaks down.

The trailer and tow vehicle were specified and bids requested. The truck which will be used as the tow vehicle for the lab was ordered and received. No responses were received from vendors for the mobile laboratory. Gellman is currently respecifying the trailer and we hope to have the mobile laboratory operational within the next six month period.

SWIR spectroradiometer: The objective of this task is to design and construct an instrument to measure surface reflectance in the SWIR region of the spectrum. When our contract began, M. Smith had already designed and built the prototype.

B. Crowther worked on the SWIR spectroradiometer to prepare it for data collection during our October White Sands field experiment. A 6-meter silicon fiber optic cable was obtained to allow the SWIR spectroradiometer to be used on the reflectomobile. Crowther and Biggar worked extensively on the electronics and temperature stabilization to prepare it for use on a helicopter. The spectroradiometer was not flown during the October experiment because of flight scheduling difficulties and weather. It was attached to the reflectomobile and several spectra were obtained over the test site. Gellman and Crowther are working with these data to convert them to reflectance. The results will be compared to data collected by other instruments attached to the reflectomobile.

BRDF Meter: The objective for this task is to design and construct a device, and develop software for measuring the directional reflectance and inferring the bi-directional reflectance distribution function of the ground. The basic design incorporates a fisheye lens and a CCD-array detector.

M. Brownlee continued work on data acquisition software for the BRDF camera. She performed preliminary measurements with the camera in our blacklab and prepared the BRF camera for use at White Sands. A tripod mount was fabricated. Brownlee modified the instrument hardware to allow it to be moved for spatially sampling BRF. She tested the instrument and developed an experiment plan for its use at White Sands. The instrument was tested during the October White Sands field experiment. Brownlee is currently examining the data and will retrieve preliminary estimates of surface BRF for comparison with results from alternate methods.

Calibration Laboratory: The objective of this project is to develop a calibration laboratory that will provide the necessary high-radiometric-accuracy standards for 1) the cross-calibration radiometers and 2) the field and aircraft radiometers needed for preflight algorithm and code validation and the actual in-flight calibration of the EOS multispectral imaging sensors beyond 1998.

Some of the equipment we intend to acquire include a spherical integrating source (SIS) to simulate at-satellite and field radiance levels and to allow intercomparison of instruments between 0.4 and 2.5 µm; stabilized lasers to provide stable discrete lines for detector-calibration and intercomparisons; cryogenic absolute radiometer to calibrate the stabilized lasers and therefore other radiometers (CCR and field); blackbody simulators for calibration of the TIR radiometers; NIST-traceable standard lamps; spectroradiometer for calibration of the SIS; and spectrophotometer. This new equipment will also require the development of methods needed to carry out the described laboratory work.

J. Palmer completed the Cary-14 spectroradiometer refurbishment and is in the process of testing. Spyak worked on characterizing the Optronic monochromator system and improving its capabilities. The monochromator system was used to measure the spectral transmittance of the VNIR CCR filters. Spyak re-examined the calibration equipment and the transfer calibration philosophy. The equipment and philosophies for the VNIR and SWIR appear to be fully sufficient. This does not appear to be true of the TIR and Spyak is continuing the investigation in this wavelength region.

Algorithm and Code Development: Currently, several algorithms exist to perform our calibration work. The RSG has applied these algorithms as FORTRAN programs which are neither user friendly nor efficiently linked together into a single package. The task objective is to convert these existing codes into ANSI standard C in a user-friendly package with rules-based decision making in the package. The group is now also involved in the atmospheric correction of ASTER data in the solar reflective portion of the spectrum.

Thome continued work on the atmospheric correction for ASTER in the solar-reflective portion of the spectrum. He emailed comments regarding test criteria for the atmospheric correction to F. Palluconi of JPL. Thome met with R. Alley, C. Leff, and C. Voge to discuss plans for the atmospheric correction. It was agreed to modify the atmospheric correction to a look-up-table approach. It was also agreed that the RSG would supply software specifications and the look-up-table for the atmospheric correction while personnel at JPL would develop the code. Thome developed preliminary software specifications and emailed them to Voge.

In related activities, Thome completed a first draft of the Algorithm and Theoretical Basis Document for the in-flight calibration of MODIS. He also added new solar ephemeris routines to the water vapor and langley retrieval programs. The Algorithm and Theoretical Basis Document for the atmospheric correction of SWIR and VNIR ASTER data will be prepared by Thome.

Field Experiments: The objectives of the field experiments are to test new equipment, determine needed improvements, test retrieval algorithms and code, and monitor existing satellites in much the same way as we shall for EOS sensors. During the six-month period, the RSG made two trips to White Sands Missile Range, one in October and another in November, and the previously described SeaWiFS calibration.

Much of the month of October was spent preparing for our field experiment at White Sands Missile Range. The purpose of the trip was to collect data for calibrations of SPOT-2 HRV, the newly-launched SPOT-3 HRV, JERS-1 OPS, and Landsat-5 TM. The trip was also used to test the BRF camera, SWIR spectroradiometer, aureole camera, newly acquired instrumentation, and modifications to the reflectomobile. An Exotech radiometer and Ocean Optics spectrometer were ordered and received. Biggar modified data collection software and hardware to accommodate constant reflectance panel data collected from the Exotech radiometer. The spectrometer was not received in time for either White Sands trip. Biggar also rewired many of the connections on our Fluke Helios data logger and constructed the cables necessary to connect new equipment to the data logger. Gellman began blacklab measurements of our reflectance panels for the field experiments. Biggar also upgraded the panel reflectance measurement and reduction software in conjunction with the blacklab work by Gellman. Thome worked on the IR thermometers and tested the software and equipment needed to collect data for the calibration of band 6 of TM in the thermal. Thome also tested the solar radiometers and meteorological instruments needed for the White Sands field experiment.

Biggar, Brownlee, Gellman, Slater, and Thome arrived at White Sands on October 15. Crowther and R. Parada arrived October 16. Brownlee, Crowther, and Parada returned October 19 while the others returned October 22. Much of the experiment was hampered by cloudiness while the rest of the trip was marred by range closures. Helicopter flights over the site were not made due to funding difficulties. Gellman has reduced the data for several of the SPOT overpasses. Thome is currently working on the Landsat-5 calibration. No attempt at a JERS-1 calibration is planned because of cloudy weather at the time of overpass.

Biggar, Gellman, Spyak, and Thome travelled to Alamogordo, New Mexico to attempt calibrations of SPOT-3 HRV, SPOT-2 HRV, Landsat-5 TM, and ERS-1 ATSR, November 18-23. The group was also joined by visiting-British-ATSR-scientist, T. Nightingale. Helicopter data were collected for the SPOT-3 calibration but this was unsuccessful due to equipment failure. Data were also collected to be used as a test of the solar-radiation-based-calibration method used in the previously mentioned SeaWiFS work. No attempt will be made at performing a calibration of Landsat-5 or ERS-1 because of poor weather on the days of overpass. Gellman has completed the data reduction for the SPOT-3 days.